

Macroeconomic Importance of Recycling and Remanufacturing

**Prepared for the Environmental Protection Agency's
Office of Solid Waste**

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1. Introduction

Most studies of recycling and remanufacturing¹ focus on environmental benefits because the major drivers - such as preventing the pollution associated with producing and refining virgin materials, reducing the amount of trees that are cut down, and decreasing the amount of material that is landfilled - of recycling and remanufacturing programs have traditionally been environmental in nature. Even though the focus of past studies has been based almost solely on environmental benefits, recycling and remanufacturing are also important from a macroeconomic perspective.

- Recycling activities employ more than 500,000 workers and produce final products worth more than \$50 billion. Further, recycling activities in the aluminum, steel, and paper industries are growing at a faster pace than the rest of these industries.
- Remanufacturing firms employ an additional 500,000 workers and have sales of more than \$53 billion.
- The amount of energy required to recycle materials is much less than that required to produce and refine virgin material. This reduces annual energy costs by more than \$15 billion.
- Recycling lowers the amount of waste that requires disposal in municipal solid waste (MSW) landfills, thereby reducing municipal solid waste annual disposal costs by nearly \$5 billion.
- Lower material production costs have contributed to the competitiveness of American industries in the international marketplace.

This study focuses on the macroeconomic importance of recycling and remanufacturing in four areas: (1) number of jobs, (2) the amount and dollar value of materials, (3) savings in material costs with a particular focus on savings in energy and waste management costs, and (4) the effect of recycling and remanufacturing on the economic competitiveness of U.S. products in the international marketplace. **Section 2** summarizes the economic importance of recycling and remanufacturing on the U.S. economy as a whole. **Section 3** details the effect of recycling on three industries: the steel industry, the aluminum industry, and the paper industry.

2. Importance of Recycling and Remanufacturing

¹For the purpose of this study, recycling is defined to include (1) processing to allow the reuse of materials and (2) reusing materials in manufacturing processes. The second part of this definition is often referred to as "manufacturing reuse." Remanufacturing starts with the disassembly of a product at which point the product's parts are cleaned, inspected, refurbished, and replaced as necessary. The parts are then reassembled and the resulting products are tested to original specifications.

2.1 What Is Recycled?

In the last two decades, the amount of material that is being recycled (and, therefore, the macroeconomic importance of recycling) has grown dramatically: in 1980, approximately 10 percent of municipal solid waste (MSW) was recycled; in 1990, individuals recycled about 17 percent of MSW; and by 1995, individuals recycled over 27 percent, more than 57 million tons, of MSW.² As Exhibit 2-1 illustrates, most of the material that is recovered from the MSW stream is paper and paperboard.³ Individuals also recycle large amounts of ferrous metals, aluminum, glass, plastic, and yard waste.

**Exhibit 2-1. Amount and Value of Recycled Material
(Millions of Tons/Billions of Dollars)⁴**

Material	Amount MSW Recycled	Total Amount Recycled	Value of Material
Paper/Paperboard	32.6	45 ⁵	--
Ferrous Metals (primarily steel)	4.5	72	\$6.8
Aluminum	1.0	3.7 ⁶	\$5.2
Other Nonferrous Metals	0.8	3.0	\$5.7
Glass	3.2	--	--
Plastics	1.1	--	--
Other Materials in Products	2.9	--	--
Other Waste	11.3	--	--
Total	57.4	--	--

²This "recycling rate" is calculated by dividing the amount of material that is recycled in the year by the amount of waste material generated in the same time frame. U.S. EPA. 1998. Characterization of Municipal Solid Waste in the United States: 1997 Update. EPA530-S-98-007. Washington, D.C.

³For the remainder of this report, we use the terms "paper" and "paper and paperboard" interchangeably.

⁴Unless otherwise stated, total amount and value are from Minerals Information Team. 1996. Recycling—Metals. U.S. Geological Survey. MSW figures are from U.S. EPA. 1998. Characterization of Municipal Solid Waste in the United States: 1997 Update. EPA530-S-98-007. Washington, D.C.

⁵1997 figures from American Forest and Paper Association. Fact Sheet on Paper and Paperboard Recovery. <www.afandpa.org/pubs/reports/advrec.html> Downloaded October 9, 1998.

⁶Plunkert, Patricia A. 1997. Aluminum. U.S. Geological Survey.

Exhibit 2-1 also shows that a large amount of material (in particular, metals) is recycled before it reaches the MSW stream. For example, 72 million tons of steel were recycled in 1996. This figure includes 1.7 million tons of steel cans (recycling rate of about 60 percent), more than 2.3 million tons of appliances (recycling rate of about 80 percent), and 13 million tons of steel from automobiles (recycling rate of about 98 percent).

2.2 Economic Importance of Recycling and Remanufacturing

Recycling and remanufacturing industries are important from a macroeconomic perspective for four reasons: (1) they directly employ individuals and supplies valuable materials and products to downstream industries, (2) they are high-growth industries, (3) they lower energy and municipal solid waste disposal costs, and (4) by lowering costs, they have improved the competitive position of some domestic industries like the steel industry. This section discusses these macroeconomic benefits. Section 3 further details these benefits for individual industries.

First, the recycling industry provides manufacturing jobs and produces valuable final products. Although no one has performed a comprehensive analysis on the economics of the recycling industry, recent studies indicate that recycling activities employ at least 500,000 workers in the manufacturing sector and produce final products worth more than \$50 billion.

Studies of Northeast⁷ and Southern States⁸ employment indicate that recycling activities⁹, excluding collection, employ at least 2.7 percent of manufacturing workers and 4.9 percent of manufacturing value added in the regions.¹⁰ Extrapolating the results of these studies to the entire nation, recycling activities account for at least 500,000 manufacturing jobs (out of a total of 19 million manufacturing jobs in the United States) and add more than \$50 billion in value to recycled materials (out of \$1.2 trillion of

⁷The "Northeast" consists of Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

⁸The "Southern States" consist of Alabama, Arkansas, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, Texas, West Virginia.

⁹These studies defined and estimated the work force for two types of recycling activities: processing and manufacturing. Processing is defined as the activity that begins after collection and ends with a material that is comparable to virgin material. Manufacturing includes the activity that is one step beyond the point at which the recovered material is comparable to virgin material. For example for plastic, the end point of manufacturing is the production of plastic sheet.

¹⁰Note that these studies significantly underestimate the number of workers employed by recycling activities because they exclude employment in collection activities and employment in industries for which they were not able to collect enough data. Ruston, John F. and Denison, Richard A., PhD. Advantage Recycling: Assessing the Full Costs and Benefits of Curbside Recycling. The Environmental Defense Fund. <www.edf.org/pubs/reports/adverc.html> Downloaded October 9, 1995; Baskin, Kathryn. 1996. Economic Benefits of Recycling in the Southern States. Southern States Energy Board.

manufacturing income).¹¹ Collection of recyclable materials employs another 25,000 workers.¹² Further, the Southern States study contained two major findings about the composition of employment in recycling industries. First, 76 percent, of the employment was in manufacturing activities. The remainder was in pre-manufacturing processing. Second, recycling activities employ a particularly large number of workers in metals (38 percent) and paper (36 percent) recycling. The remainder of recycling employment was for recycling plastic (12 percent), glass (5 percent), and multiple materials (9 percent).

As illustrated in Exhibit 2-2, approximately 270,000 workers in the steel, aluminum, and paper industries manufacture final products using recycled materials.

Exhibit 2-2. Number of Manufacturing Workers Using Recycled Material

Industry	Manufacturing Employment	Recycled Material (as % of All Material)	Employment (Using Recycled Material)
Steel	110,000 ¹³	67% ¹⁴	73,700
Aluminum	69,000 ¹⁵	42% ¹⁶	28,980
Paper	681,000 ¹⁷	25% ¹⁸	170,250
Total	860,000	33%	272,930

¹¹Employment figures were generated by multiplying 2.75 percent by total U.S. manufacturing employment and 4.9 percent by total U.S. manufacturing income. Department of Labor. Bureau of Labor Statistics. 1998. Household Survey Data; Department of Commerce. Bureau of Economic Analysis. 1998. Survey of Current Business: National Income and Product Accounts Tables. August.

¹²Figure was derived by multiplying the MSW recycling rate, 27 percent, by the total number of jobs in Refuse and Recyclable Material Collection. Bureau of Labor Statistics. 1996. Occupational Employment Statistics (OES) National Industry Staffing Pattern Estimates. Washington, D.C.

¹³American Iron and Steel Institute. 1998. Annual Statistical Report, 1997. Washington, DC

¹⁴Steel Recycling Institute. The Inherent Recycled Content of Today's Steel. <www.recycle-steel.org/buy/BuyInherent.html> Downloaded October 7, 1998.

¹⁵Figure consists of the employment in three aluminum-related manufacturing industries (Primary Aluminum; Aluminum Sheet, Plate, and Foil; and Aluminum Foundries). Employment information for three additional aluminum manufacturing industries (Aluminum Extruded Products; Aluminum Rolling and Drawing; and Aluminum Die-Castings) is not published. Bureau of Labor Statistics. 1997. National Employment, Hours, and Earnings. <146.142.24/cgi-bin/dsrv> Downloaded October 22, 1998.

¹⁶This figure was calculated as secondary recovery of aluminum divided by apparent supply of aluminum. Plunkert, Patricia A. 1997. Aluminum. U.S. Geological Survey.

¹⁷Engel, Cynthia. 1997. Taking Note of Paper Industry. Monthly Labor Review.

¹⁸Institute of Scrap Recycling Industries. 1996. Scrap Recycling: Where Tomorrow Begins. Washington, D.C.

In addition to the economic importance of recycling activities, 73,000 remanufacturing firms employ 480,000 workers and have sales of \$53 billion per year. Although remanufacturing occurs in many industries, as Exhibit 2-3 illustrates, the majority of remanufacturing employment and sales are in five industries: (1) automotive, (2) electrical apparatus, (3) tires, (4) toner cartridges, and (5) office furniture.¹⁹

**Exhibit 2-3. Employment and Sales (in Millions of Dollars)
in Remanufacturing Industries**

Industry	Sales	Employment
Automotive	\$36,546	337,571
Electrical Apparatus	\$4,633	47,280
Tires	\$4,308	27,907
Toner Cartridges	\$2,475	31,872
Office Furniture	\$1,663	12,148
Valves	\$589	4,577
Machinery	\$434	3,155
Compressors	\$249	2,878
Other	\$2,009	14,372
Total	\$52,906	481,760

Second, as was discussed above in Section 2.1 and is discussed in more detail in Section 3, recycling is a growing industry. Three examples best illustrate the recent and anticipated future growth in the recycling industry.

- The amount of MSW being recycled has increased dramatically: in 1980, approximately 10 percent of municipal solid waste (MSW) was recycled; by 1995, individuals recycled over 27 percent, more than 57 million tons, of MSW.
- The steel minimill industry, whose feedstock is scrap steel, has grown significantly over the past decades: from 14 million tons of steel in 1965, to 31 million tons in 1980, and 48 million tons in 1997 (see Exhibit 3-2). Over this same period, the steel production of integrated firms (whose feedstock is virgin ore and a small percentage of scrap steel) declined by nearly 50 percent. Further, the current growth rate for minimills is significantly higher than that for integrated steel producers.
- Paper producers almost doubled their use of scrap paper between 1985 and

¹⁹Lund, Robert. 1996. The Remanufacturing Industry: Hidden Giant. Boston University. Boston, MA.

1995²⁰ and estimates are that worldwide demand for recycled paper will increase from 110 million tons in 1993 to 150 million tons by the year 2000.²¹

Third, recycling reduces energy costs significantly and is a substitute for disposal, completely eliminating disposal costs (as is discussed in more detail in Section 3, these cost savings make recycling aluminum, steel, and paper more economical than producing and refining virgin material). On average, the energy required to recycle aluminum, copper, iron and steel, lead, zinc, paper, and plastics is 75 percent less than the energy required to produce and refine similar virgin materials. Of particular note, the energy required to recycle aluminum and ferrous materials are, respectively, 95 and 74 percent less than that required to produce and refine similar virgin materials.²²

As Exhibit 2-4 illustrates, recycling steel, aluminum, paper, glass, and plastic reduces energy costs by more than \$15 billion.²³ Also, using a disposal cost of \$37 per ton²⁴, the cost savings from avoiding disposal are an additional \$5 billion.

²⁰Engel, Cynthia. 1997. Taking Note of Paper Industry. Monthly Labor Review.

²¹Engel, Cynthia. 1997. Taking Note of Paper Industry. Monthly Labor Review.

²²Institute of Scrap Recycling Industries. 1996. Scrap Recycling: Where Tomorrow Begins. Washington, D.C.

²³This figure does not take into account the fact that recycling programs (e.g., collection and processing) also consume energy. This omission, however, has only a small effect. A 1994 study -- Ruston, John F. and Denison, Richard A., PhD. Advantage Recycling: Assessing the Full Costs and Benefits of Curbside Recycling. The Environmental Defense Fund. <www.edf.org/pubs/reports/adverc.html> Downloaded October 9, 1995. -- showed that the energy consumed by curbside recycling programs is only ten percent of the energy savings from recycling materials.

²⁴Chartwell Information Publishers. 1997. Solid Waste Digest: National Edition. Volume 7. Number 9.

Exhibit 2-3. Cost Savings From Recycling (Total Savings in Millions of Dollars)

Material	Energy Savings per Ton		Disposal Cost per Ton	Total Energy Cost Savings	Total Disposal Cost Savings
	Mil. BTU ²⁵	Dollars ²⁶			
Steel	11.4	\$94	\$37	\$6,800	\$2,700
Aluminum	177.2	\$1,473	\$37	\$5,500	\$140
Paper ²⁷	11.7	\$97	\$37	\$4,400	\$1,700
Glass	2.3	\$18	\$37	\$60	\$100
Plastics	77.3	\$642	\$37	\$700	\$40
Total	n.a.	n.a.	\$37	\$17,460	\$4,680

Fourth, as is discussed in more detail in section 3.1, after years of decline, the steel industry was reinvigorated by minimills, which recycle scrap steel. Because the technology used by minimills produces certain types of steel more cost-effectively than the basic oxygen furnaces used by integrated firms, U.S. minimills have been able to compete more effectively with foreign steel mills than have integrated firms.

6. Industry Case Studies

3.1 The Steel Industry

Until recently, American steel companies were integrated firms that transformed virgin iron ore, coal, and limestone into steel. To make steel, these companies first mined and beneficiated iron ore. They next produced pig iron by combining iron pellets and sintered ore, coke, and limestone in a blast furnace. Finally, they heated pig iron and scrap steel (limited to less than 30 percent of mixture) in an open hearth or basic oxygen furnace to produce molten steel to be casted and milled to produce a final product.

Facing a significant decline in domestic steel consumption and intense foreign competition, steel production by integrated firms dropped almost fifty percent between 1970 and 1985. Although price competition was not the only reason for this decline, it was a major contributor. As Exhibit 3-1 shows, the market penetration of imported

²⁵Ruston, John F. and Denison, Richard A., PhD. Advantage Recycling: Assessing the Full Costs and Benefits of Curbside Recycling. The Environmental Defense Fund. <www.edf.org/pubs/reports/adverc.html> Downloaded October 9, 1995.

²⁶Calculated using 1994 average price data from Energy Information Administration. 1997. Annual Energy Review. U.S. Department of Energy. Washington, D.C.

²⁷All figures for paper are from Duke University, et. al. 1994. The Paper Task Force: Final Report. All figures include the life-cycle energy estimates of virgin production and landfilling or incineration versus recycled production and recovery (i.e., transportation, etc.).

steel increased as domestically-produced steel became more expensive relative to imported steel.²⁸

Exhibit 3-1. Price Competitiveness and Market Penetration of Imported Steel

Sector/Product	Ratio of Domestic Price to			Ratio of Imports to Domestic		
	1971-75	1976-80	1981-84	1971-75	1976-80	1981-84
Integrated Firm						
Hot-Rolled Sheets	0.91	1.04	1.04	0.14	0.14	0.16
Cold-Rolled Sheets	0.94	1.05	1.06	0.19	0.17	0.19
Plates	1.02	1.24	1.30	0.23	0.35	0.53
Structural Sheets	1.00	1.17	1.12	0.25	0.42	0.60
Minimills						
Hot-Rolled Bars	1.02	1.11	0.98	0.10	0.08	0.08
Wire Rods	1.10	1.07	0.98	0.72	0.38	0.37

During this same time period, a new steel industry - the minimill industry - emerged. The production process in this industry is based on recycling old steel: the basic technology used - the electric furnace - melts scrap steel to produce molten steel. Although this process cannot produce all types of steel, minimills are able to produce specialized types of steel, including hot-rolled bars and wire rods, at a price competitive with the price of imports (see Exhibit 3-1 above). As shown in Exhibit 3-2, this recycling industry has prospered, growing both in share of domestic steel production (about 300 percent over the last 30 years) and absolute tonnage (nearly 250 percent since 1965). At the same time, the integrated steel industry has declined. As a result of the increase in minimill production, recycled steel comprises about 67 percent of the feedstock for steel production.²⁹

²⁸Crandall, Robert and Barnett, Donald. 1986. Up From the Ashes: The Rise of the Steel Minimill in the United States. The Brookings Institute. Washington, DC.

²⁹Steel Recycling Institute. The Inherent Recycled Content of Today's Steel. <www.recycle-steel.org/buy/BuyInherent.html> Downloaded October 7, 1998.

Exhibit 3-2. Raw Steel Production, by Furnace Type (Millions of Tons)³⁰

Year	Integrated Firm		Minimills (Electric)		Total
	Weight	%	Weight	%	Weight
1997	61.1	56%	47.5	44%	108.6
1995	62.5	60%	42.4	40%	104.9
1990	62.0	63%	36.9	37%	98.9
1985	58.3	66%	29.9	34%	88.2
1980	80.6	72%	31.2	28%	111.8
1975	94.0	81%	22.7	19%	116.7
1970	111.3	85%	20.2	15%	131.5
1965	117.1	89%	13.8	11%	130.9

The minimill industry is important from an economic perspective. It is a large (it produced 47.5 tons of steel, accounting for 44 percent of domestic steel production) and growing portion of the steel industry. In 1997, the steel industry employed nearly 110,000 workers at a high wage, the average employment cost per hour being more than \$35.³¹ The minimill industry is particularly important because some of these jobs would likely have been lost to foreign competition if this segment of the steel industry had not emerged.

3.2 The Aluminum Industry

In 1997, the aluminum industry recycled 3.7 million metric tons of aluminum, 2.2 million metric tons of new scrap (scrap that results from the manufacturing process, including metal and alloy products) and 1.5 million metric tons of old scrap (scrap that results from consumer products). Although the amount of aluminum that is recycled annually is significantly less than the amount of steel that is recycled annually (72 million metric tons), the value of the recycled aluminum (\$5.2 billion) is nearly as much as that of recycled steel (\$6.8 billion). This is because the unit value of aluminum is much higher than that for steel. Because the value of aluminum is so high (the purchase price of a pound of scrap aluminum is 50-60 cents), aluminum recycling is a very cost-effective alternative to disposal.³²

Because the primary source of old scrap is aluminum cans (aluminum cans make up more than 50 percent of old scrap) and the value of this scrap is high, the aluminum can industry started an aluminum can recycling program in 1968. By 1997, this program

³⁰American Iron and Steel Institute. 1986. Annual Statistical Report, 1985. Washington, DC; American Iron and Steel Institute. 1998. Annual Statistical Report, 1997. Washington, DC

³¹American Iron and Steel Institute. 1998. Annual Statistical Report, 1997. Washington, DC

³²As discussed earlier, the major reason why scrap aluminum is valuable is that the energy required to recycle scrap aluminum is 95 percent less than that required to make aluminum from virgin bauxite ore. Figures are from Plunkert, Patricia A. 1997. Aluminum. U.S. Geological Survey; Minerals Information Team. 1996. Recycling-Metals. U.S. Geologic Survey.

had grown significantly both in terms of the proportion of cans being recycled and in economic importance.

- In 1997, two billion pounds, or two-thirds, of used aluminum cans were recycled.
- In 1996, the aluminum industry spent \$1.08 billion to buy back aluminum cans.
- Aluminum cans currently represent less than 0.5 percent of the municipal solid waste.³³
- In 1997, the recycled content of newly manufactured aluminum products reached 42 percent.³⁴
- In 1996, the amount of energy saved by the aluminum can industry alone was equivalent to 18.4 billion barrels of oil or 10.8 billion kilowatt hours of electricity.³⁵

3.3 The Paper Industry

Unlike scrap aluminum and steel, the majority of recycled paper is collected through curbside and other recycling programs. Because these collection programs duplicate, rather than replace, existing municipal refuse collection programs, the cost of paper collection programs have traditionally been more expensive than the cost of disposing scrap paper as municipal solid waste. This is not to say that these programs have no economic benefit: in 1995, the price for scrap paper offset the incremental cost to some cities for running a curbside collection programs. Seattle, Washington actually made \$5 million in 1995.³⁶

Due to greater operating efficiency for recycling programs and higher prices for recovered materials, curbside recycling programs are becoming increasingly cost-effective and popular. This has caused the recycling rate for paper to increase significantly: from 29 percent in 1987, to 38 percent in 1992, and to 45 percent in 1997.³⁷ In fact, paper producers almost doubled their used of scrap paper between

³³Institute of Scrap Recycling Industries. 1998. 1997 Aluminum Can Recycling Rate Reaches 66.5%. <www.isri.org/viewpage.cfm?pgid=63> Downloaded October 7, 1998.

³⁴Plunkert, Patricia A. 1997. Aluminum. U.S. Geological Survey

³⁵Plunkert, Patricia A. 1997. Aluminum. U.S. Geological Survey; Can Manufacturers Institute. The Aluminum Can Success Story. <www.cancentral.com/success1.htm> Downloaded October 7, 1998.

³⁶Duke University, et. al. 1994. The Paper Task Force: Final Report.

³⁷American Forest and Paper Association. Fact Sheet on Paper and Paperboard Recovery. <www.afandpa.org/pubs/reports/advrec.html> Downloaded October 9, 1998.

1985 and 1995.³⁸ As a result, the recycled content of paper fiber is an estimated 25 percent.³⁹

The increasing cost-effectiveness of curbside recycling stems from the increasing value paper producers place on scrap paper. There are two ways to make paper: (1) cellulose is extracted from virgin fiber, bleached, beaten, and rinsed and (2) recycled recycling plants repulp the fiber in scrap paper, feed the pulp into an ink removal system, and combine with virgin fiber. There are three major benefits of the latter process for refining recycled fiber over the former process - (1) production using recycled paper takes less energy, (2) the total cost of the recycling process is 20 percent less, and (3) recycling mills are smaller scale and can be installed at a lower cost per ton than virgin paper mills.⁴⁰

Processing recycled paper results in a significant number of jobs: in 1997, the paper and allied products manufacturing industry employed approximately 681,000 workers. The economic importance of recycling paper is also likely to continue growing in the near future. Because of their smaller size and lower capital cost, much of the expansion in paper production will be handled through the construction of recycling mills. For this reason, estimates are that worldwide demand for recycled paper will increase from 110 million tons in 1993 to 150 million tons by the year 2000.⁴¹

³⁸Engel, Cynthia. 1997. Taking Note of Paper Industry. Monthly Labor Review.

³⁹Institute of Scrap Recycling Industries. 1996. Scrap Recycling: Where Tomorrow Begins. Washington, D.C.

⁴⁰Ibid.

⁴¹Engel, Cynthia. 1997. Taking Note of Paper Industry. Monthly Labor Review.

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U.S. EPA. 1998. Characterization of Municipal Solid Waste in the United States: 1997 Update. EPA530-S-98-007. Washington, D.C.